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THE POLARIZED INTERNAL GAS TARGET OF ANKE AT COSY

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A first storage cell for the Polarized Internal gas Target (PIT) of the ANKE facility at COSY was produced from a Teflon-coated pure Aluminum foil and successfully used in the double polarized experiment with a 1.2 GeV polarized deuteron beam carried out at the COSY accelerator in January 2007. Prior to this experiment, the minimum possible cross section of the storage-cell beam tube at the interaction point at ANKE was determined, based on the COSY beam profile at different beam formation stages. Electron cooling combined with stacking and stochastic cooling have been studied as well. Experiments with N_2 gas in the storage cell to simulate the background produced by beam interaction with the aluminum cell walls were performed. The analysis of the $\vec{d}\vec{p}\rightarrow$dp and $\vec{d}\vec{p} \rightarrow (dp_{sp})\pi^0$ reactions showed that events from the extended target can be clearly identified in the ANKE detector system. Taking into account the known intensity of the Atomic Beam Source (ABS), the expected target density in the experiment with a storage-cell beam tube of $15_{hor} \times 20_{vert} \times 390_{long}$ mm^3 and a 130 mm long feeding tube with 15 mm diameter reach values of 3.2×10^{13} at/cm^2. The polarization, measured by the $np \rightarrow d\pi^0$ reaction with the storage-cell, was 0.75 ± 0.06.

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1. Introduction

The development of the ANKE Atomic Beam Source (ABS)[1], which produces polarized hydrogen or deuterium beams (the main parameters of the source are shown in Table 1) was successfully finished in 2003.

Table 1. Main parameters of the polarized beam source of ANKE/COSY.

Gas Type	Intensity, at/s	Pz	Pzz
Hydrogen	$(7.8 \pm 0.2) \times 10^{16}$	$+0.89 \pm 0.01$	-
		-0.96 ± 0.01	-
Deuterium	$(3.9 \pm 0.1) \times 10^{16}$	$+0.73$	$+0.77$
		-0.82	-1.17

In the subsequent two years the ABS together with the Lamb-shift Polarimeter (LSP)[2] was transferred from the laboratory to the COSY building and reassembled on a special support bridge between two columns, representing the first beam-bending magnet $D1$ and the spectrometer magnet $D2$ of ANKE (see Fig. 1).

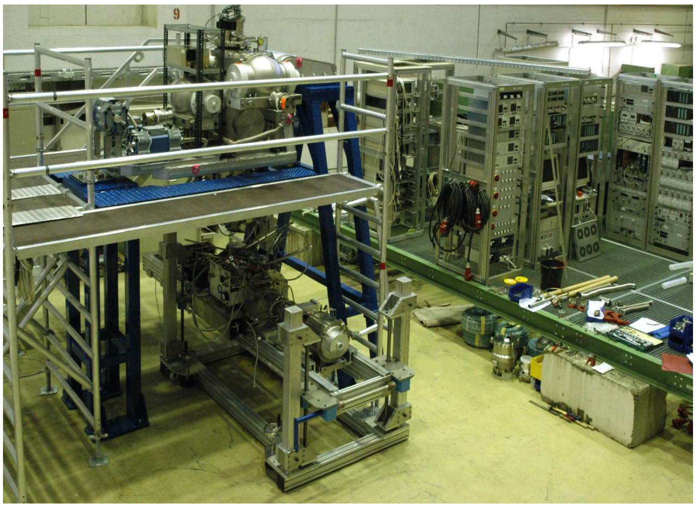

Fig. 1. The ABS in the accelerator hall near the COSY tunnel.

This figure also shows the platform for the transportation of the infrastructure (electronic and the power-supply modules, gas bottles, cooling devices, etc.) from the occupied place to the ANKE experimental area. In summer 2005, after all necessary tests were carried out, the source was ready for installation at the spectrometer ANKE for further commissioning. Measurements to determine the COSY-beam dimensions and minimal possible storage cell cross section at the ANKE-target position as well as a tests with storage-cell prototypes were carried out in parallel to this studies.

2. COSY Beam Studies

To achieve the maximum luminosity in the experiments with the polarized internal gas target one had to determine the smallest possible size of the storage-cell tube. During the test[3] with diaphragms in February 2004 the diameter of the unpolarized proton beam at different beam formation stages (at injection energy of 45 MeV and after acceleration to 2.65 GeV) at the ANKE target position was measured. For this, a frame carrying various diaphragms was constructed. The large diaphragm, which was mainly used during the measurements, had dimensions of $50_{hor} \times 25_{vert}\ mm^2$, i.e. substantially bigger than the expected beam size to keep all injected particles in the beam. In order to move the frame, a XY manipulator was mounted at the target chamber as is shown on the left side Fig. 2.

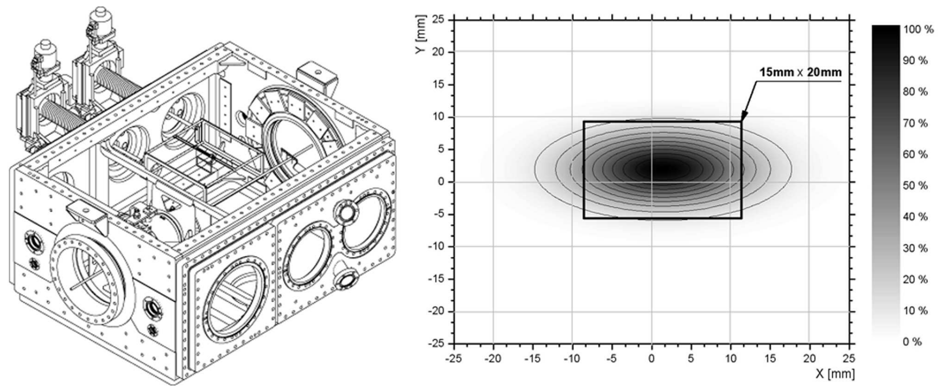

Fig. 2. **Left side:** The moveable frame in the target chamber of ANKE. **Right side:** Reconstructed two-dimensional COSY beam profile at the injection energy of 45 MeV.

During the tests, the supporting frame was moved by stepper motors. First, the center of the diaphragm was placed at the expected center of the COSY beam. By moving the diaphragm, the beam is gradually destroyed and its full size can be measured. At injection, the beam had an elliptical shape and its full size was about $38_{hor} \times 17_{vert}\ mm^2$ (right side Fig. 2). The measurements with accelerated beam with and without target showed that to be on the safe side for the upcoming experiments at ANKE the storage-cell beam tube should be $20_{hor} \times 15_{vert}\ mm^2$.

3. Atomic beam source at ANKE

In summer of 2005 the ABS was installed for the first time at the ANKE facility between the bending magnet $D1$ (on the left side from the ABS on Fig. 3) and the spectrometer magnet $D2$ (on the right side side). To operate the ABS a shielding from the strong magnetic stray field of the $D2$ magnet is required. For instance, most of the components with movable parts (like turbomolecular and cryogenic pumps) can be damaged in high magnetic fields, or vacuum gauges for monitoring of the source operation give the wrong pressure during ramping of the magnets, which

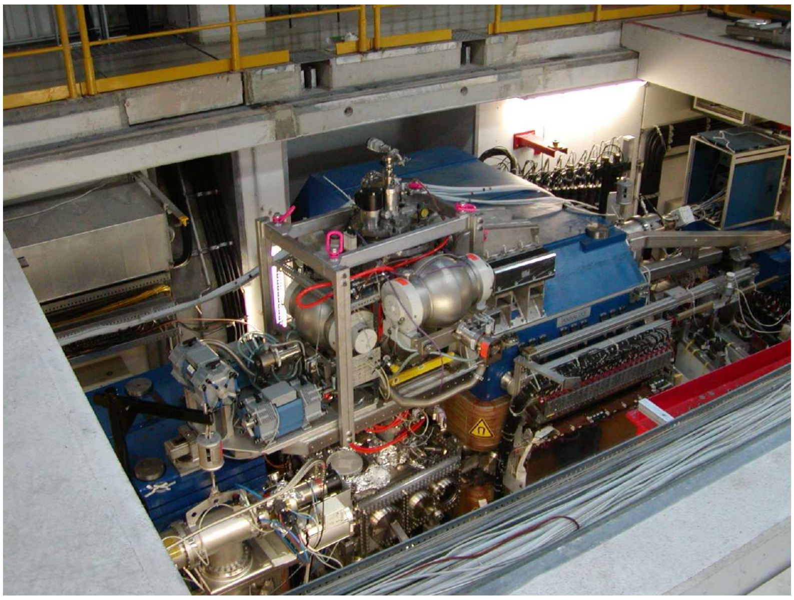

Fig. 3. The ABS in the COSY tunnel, mounted on top of the target chamber. The COSY beam enters the setup from the left.

can initiate an emergency shutdown of the source. In a first polarized run (with polarized target and unpolarized beam) in autumn of 2005 we realized, that the weak field transition (WFT) unit, following the last sextupole magnet of the ABS, did not change the population of the hydrogen atoms in the beam from hyperfine state (HFS) 1 into HFS 3. During the measurement of the magnetic field along the ABS beam axis is was observed that the stray field in the region of the WFT was larger than expected and, therefore, the WFT was not induced. In a following beam time the shielding of the WFT unit was improved and the LSP was used to tune transition units with the $D2$ magnet switched on.

4. Polarized internal target at ANKE

For a new prototype of the storage cell an aluminum foil covered with Teflon to minimize the depolarization on the surface was used. The beam tube was 400 mm long and had a cross-section of $20_{hor} \times 20_{vert}\ mm^2$. During the run, stacking injection[4] and electron cooling were used to increase the number of stored and accelerated protons with the storage cell in place (see left side of Fig. 4). As a last step, the ANKE spectrometer magnet $D2$ was moved to the position which corresponds to a deflecting angle of $9.2\,^\circ$. At this configuration 6.4×10^9 protons could be stored and accelerated in the ring (about 50% from the total number of accelerated particles without cell and stacking at injection). This number yields an appreciable luminosity of 10^{29} cm^{-2}s^{-1} for double polarization experiments.

For the COSY beam energies higher than 831 MeV stochastic cooling can be applied. This allows one to compensate for the beam heating by the target. On the right side of Fig. 4 the full trigger rate during data acquisition is shown as a function of time during different beam cycles. When stochastic cooling is switched off and the beam is heated, the rate of beam particles interacting with the cell walls is increased and the background is growing dramatically. With stochastic cooling, the beam heating is compensated and the trigger rate did not increase during the cycle.

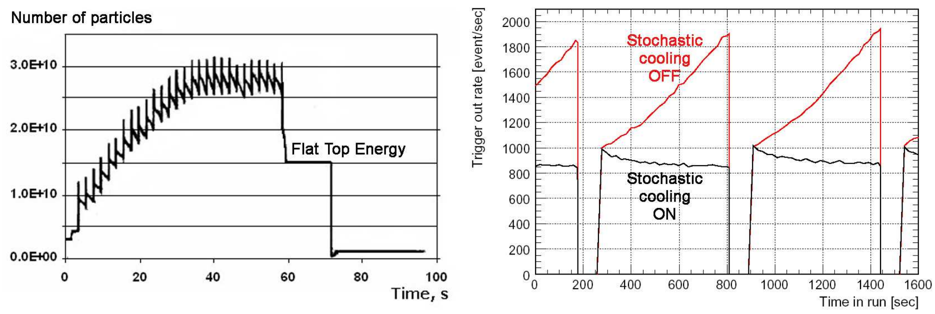

Fig. 4. **Left side:** The number of the stored protons in the COSY ring during stacking (28 stacks through a storage cell followed by 2 s of electron cooling) and accelerating to flat top energy. **Right side:** The trigger rate during data tacking with stochastic cooling switched on and off. The strong increase of the trigger rate with switched off stochastic cooling occurs due to the beam heating and interactions with a storage-cell walls.

In early 2007, the LSP was used to tune and to control the polarization of the ABS beam. However, the magnetic stray field of the spectrometer magnet $D2$ caused a number of problems:

- The slow protons behind the Glavish-type ionizer of the LSP were partially deflected and, therefore, the sensitivity of the LSP was decreased.
- The quantization axis of the polarization, defined in the longitudinal solenoid field of the ionizer, was deflected, too. The LSP measures the projection of the polarization on the horizontal beam line only. The measured polarization was about 22% of the expected value only and, furthermore, it had the wrong sign.

Nevertheless, the transition units could be tuned and the polarization, which was measured once per day, could be controlled to be stable within 5% during one week of operation.

In this beam time a storage cell with size of $20_{hor} \times 15_{ver} \times 380_{long}\ mm^3$ was used, made from 25 μm aluminum foil covered with 5 μm Teflon. In addition H_2 and N_2 could be injected into the cell by two separate gas feeding tubes. A first silicon tracking telescope (STT)[5] was mounted nearby the storage cell center (about 10 mm from the cell wall). Polarized or unpolarized deuterons were accelerated to the flat top energy of 1.2 GeV through the storage-cell tube filled with polarized hydrogen from the ABS or with unpolarized H_2 or N_2 gas from the calibrated gas supply system.

The analyzing powers for the reaction $d\vec{p} \to (dp_{sp})\pi^0$ for different scattering angles are known[7] with good precision. Based on the measured asymmetries, the polarization of the hydrogen atoms in the cell was determined with an unpolarized deuteron beam as 0.75 ± 0.06. Vice versa, the polarization of the COSY beam can be observed with unpolarized hydrogen in the storage cell as well.

5. Summary and Outlook

After implementation of the polarized internal target with asymmetric storage cell of $20_{hor} \times 15_{ver} \times 390(160+230)_{long}\ mm^3$ at ANKE double polarized $\vec{d}\vec{p}$ experiments were carried out in the beginning of 2007. With polarized hydrogen target density of 2×10^{13} atoms/cm^2 in one hyperfine state (1 or 3) and a COSY beam intensity of 7×10^9 stored polarized deuterons in the ring a luminosity of about 2.5×10^{29} cm^{-2}s^{-1} has been achieved. The polarization of the hydrogen atoms in the storage cell was measured by nuclear reactions to be about 0.75 ± 0.06.

For the coming beamtime in the beginning of 2009 a long beam time at ANKE on double-polarized $\vec{p}\vec{d}$ breakup is planned at flat top energies 1.2 or 2.23 GeV[8]. The modified Lamb-sift polarimeter equipped in addition with a rotatable Wien filter, which will be used for compensation of the misalignment of the polarization axis, and sophisticated shielding from the stray field of $D2$ magnet will be implemented beneath the target chamber. It will allow one to measure absolute polarization of the target gas in the storage cell online.

6. Acknowledgments

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